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Assessing radio frequency electromagnetic field exposure with a wearable network of dosimeters

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Abstract

In contrast to the tremendous increase of wireless applications, the knowledge about daily life radio frequency electromagnetic field (RF-EMF) exposure remains low. Some research has already been conducted using large commercial single-antenna on-body dosimeters to assess daily RF-EMF exposure in different environments. To increase measurement quality and decrease variability however, a distributed, wearable body sensor network spread over the body for the assessment of RF-EMF exposure is desired. As a better alternative to the common single node assessment technique, this work therefore presents a wearable sensor network consisting of five nodes for the assessment of exposure in the 389 to 464, 779 to 950 and 2400 to 2483.5MHz bands using only two transceivers per node. A single node supports an antenna connection for the first band, two for the second and two for the third band. This makes antenna diversity possible and hence increases sensitivity for specific frequencies, depending on the choice of antenna design. Every node is powered by two AAA batteries, which define the size of the system (53x25x15mm), making it smaller than any other commercially available dosimeter. Furthermore, the device supports an inertial sensor for the assessment of body posture and/or activity during the measurement.

Keywords: exposure, wearable, sensor network, RF, dosimeter, inertial, on-body

Introduction

Controversy exists concerning the health effects of radiofrequency electromagnetic field (RF-EMF) exposure due to the widespread use of wireless RF technology in current daily life environments. The World Health Organisation's (WHO) Research Agenda for Radiofrequency Fields has stipulated that dosimetric evaluations are indispensable in the development and validation of radio frequency electromagnetic field (RF-EMF) exposure assessment methods in epidemiological research. Also, RF-EMF multisource exposure measurements are preferred over exposure from single sources [1].

The state of the art exposimeters have been shown to introduce very large uncertainties due to shadowing of the body and varying body positioning [2-6]. The human body reflects and absorbs RF-EMFs, causing the measurements of the exposimeter to show the resulting electric fields (i.e. after body effects) instead of the incident fields, which truly represent exposure levels. Previous work has shown that a distributed measurement approach using a body area network (BAN) can significantly reduce these uncertainties [7].

This work presents a novel wearable personal distributed exposimeter (PDE) that registers body exposure using a wireless body area network (BAN) of sensing units for multiple RF bands. The system consists of five identical nodes that record received power in the 779 to 950 and 2400 to 2483.5MHz bands using only two transceivers per node by using an antenna diversified architecture.

Material and Methods

Frequencies of interest

The goal of this research is to assess commonly used frequencies. Therefore, we chose to measure the GSM-900 up- and downlink bands and the 2.4Ghz band, which contains Wi-Fi, Bluetooth, ANT and other common IEEE 802.15 standards. Moreover, the system is able to assess the 2.4GHz band in two perpendicular polarizations in order to achieve more exposure information in this band. The 433MHz ISM-band is currently being used as the information carrier for the transmission of information over the wireless BAN, which connects the different measurement nodes and centralizes the data at a personal computing device.

433MHz & GSM-900

To assess GSM-900 exposure and to cover the BAN communication, a CC430F5135 [Texas

Dual polarised 2.4GHz

The diagram shows the CC2530 module connected to the CC430 module via an SPI interface. The CC2530 module has two RF ports, RF_N and RF_P, which are connected to a BALUN block labeled 'BALUN 2450MHz'. This block has two outputs: '2450MHz vertical' and '2450MHz horizontal'. The CC430 module has two RF ports, RF_N and RF_P, which are connected to two BALUN blocks. The top BALUN block is labeled 'BALUN 900/950MHz' and has two outputs: '900MHz' and '950MHz'. The bottom BALUN block is labeled 'BALUN 433MHz' and has one output: '433MHz'.

Fig. 1: A schematic overview of the system's architecture

The two transceivers in the PDE provide a continuously updated received signal strength indicator (RSSI) value, which is used to quantify the incoming RF-EMF. The RSSI is a measure of RF input power and is based on the gain setting of the transceivers [8].

Results

The resulting PCB layout of a single system node was fitted to a double AAA battery holder, giving it a small size of 53x25x15mm compared to existing dosimeters such as the EME Spv 140

Fig. 2: A single node's PCB with the switches indicated with "S"

Discussion

Future work should provide reliable information about the value of IMU measurements combined with the assessment of RF-EMF exposure. IMU information may provide essential information about effects of the human body on the resulting electric fields, creating the opportunity to take body posture into account during the experiments.

Conclusions

This paper has presented a novel approach for PDE design in a wireless BAN. It reduces the BOM for the assessment of multi-source RF-EMF exposure assessment by the use of antenna diversity. The resulting system is an important step in the development and validation of radio frequency electromagnetic field (RF-EMF) exposure assessment methods in epidemiological research. Furthermore, the small size of the PDE increases the wearability of the system compared to existing exposimeters.

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